Recent Progress on the GSMaP_Gauge Product

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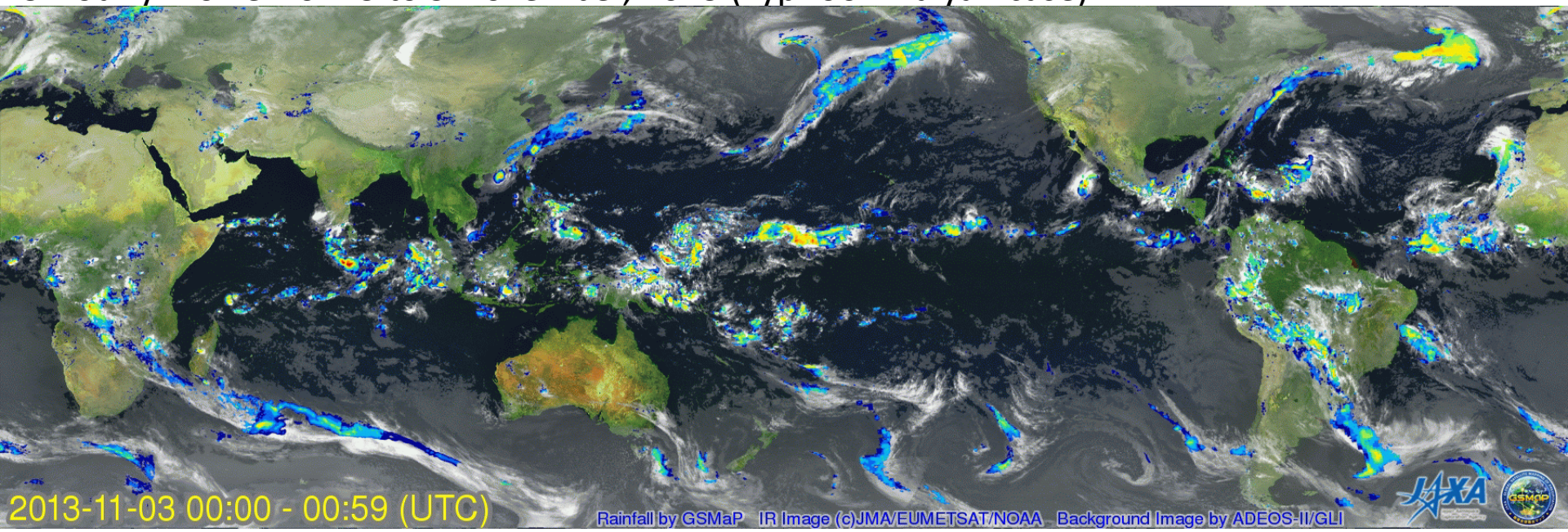
Contents

- Overview of the GSMaP_Gauge product

- Optimization of the parameters in the GSMaP_Gauge algorithm
  - Weighting parameter determing the ratio of the gauge measurement to satellite measurement
  - Parameters characterizing precipitation estimates in the algorithm

Global Satellite Mapping of Precipitation (GSMaP)

3-hourly movie from 3 to 9 November, 2013 (Typhoon Haiyan case)



- GSMaP is a blended Microwave-IR product and has been developed in Japan, and its data sets are supplied through the JAXA website since 2007.
- These data sets have been widely used by more than 1500 organizations all over the world.

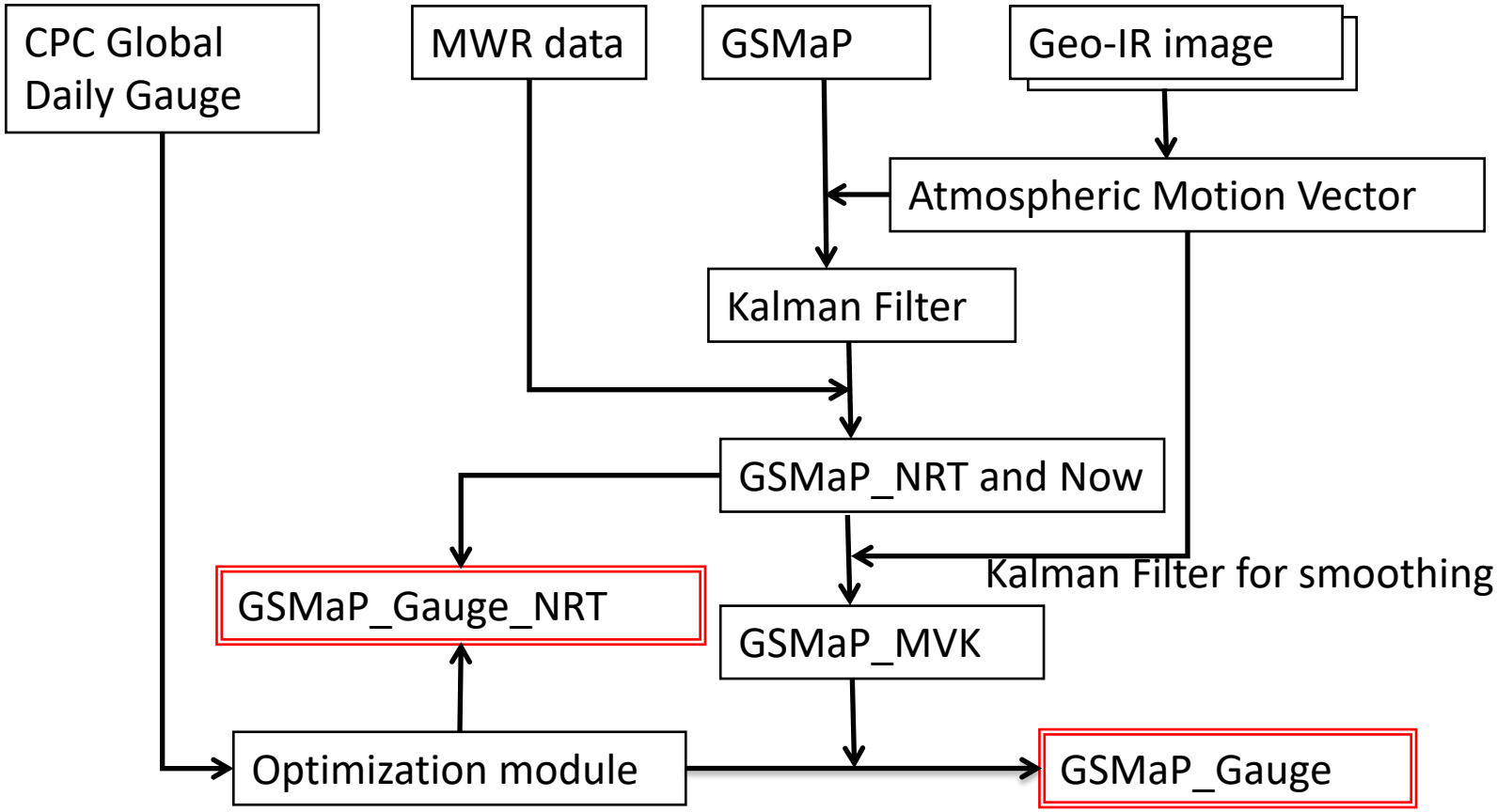
Current GSMaP products

- GSMaP_MWR
  - Microwave radiometer product
- GSMaP_MVK
  - Global precipitation mapping from microwave and infrared radiometric data
- GSMaP_NRT and GSMaP_Now
  - Near real time version of the GSMaP_MVK product
  - Lower precision compared to the GSMaP_MVK
- GSMaP_Gauge
  - Gauge adjusted GSMaP_MVK
- GSMaP_Gauge_NRT
  - Near real time product of GSMaP_Gauge

Satellite only products

Gauge adjusted products

GSMaP algorithm flow



System Model of the GSMaP_Gauge product

$$\begin{cases} GSMaP\_Gauge_{t+1} = GSMaP\_Gauge_t + \sigma_{w_t} \\ GSMaP\_MVK_t = c \times GSMaP\_Gauge_t + \sigma_{v_t} \\ \sum_{t=1}^{24} GSMaP\_Gauge_t = CPC\_Gauge \end{cases}$$

Parameters characterizing precipitation estimation

Based on this system model, the optimal solution for GSMaP_Gauge is derived by minimizing the cost function.

Cost Function

Gauge term

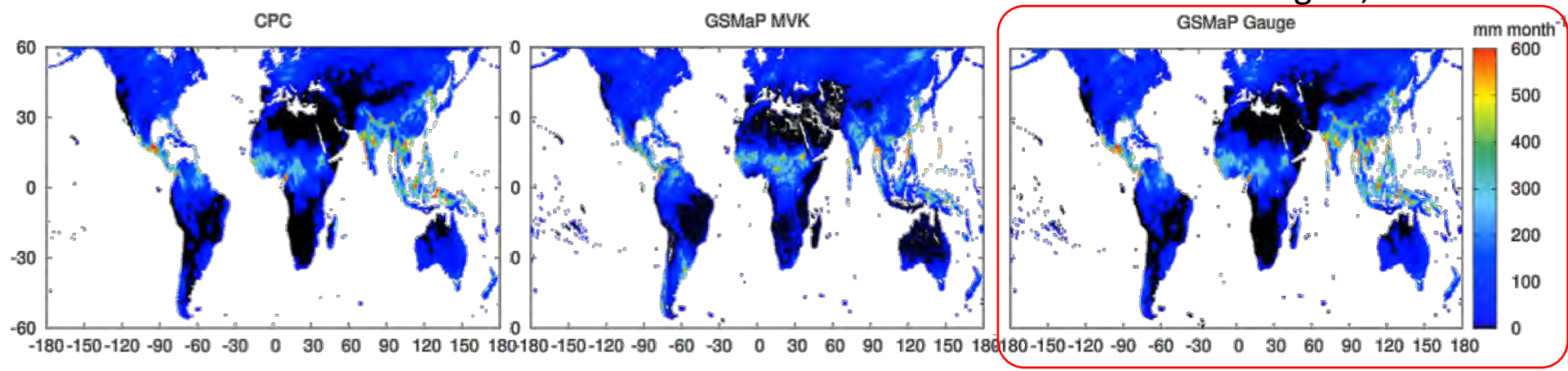
$$L(a) = -\ln\left\{ \Pr(\mathbf{x},\mathbf{a}) \times e^{\frac{\lambda}{2}\left(\sum_{n=1}^{N} a_n - W\right)^2} \right\}$$

$$= -\ln\left[\Pr(a_1)\prod_{m=1}^{24}\Pr(a_m|a_{m-1})\prod_{n=1}^{24}\Pr(x_n|a_n) \times e^{\frac{\lambda}{2}\left(\sum_{n=1}^{N} a_n - W\right)^2} \right]$$

- In a word, based on the assumption that the GSMaP_Gauge – CPC Gauge data (Gauge term) has the gaussian distribution, we maximize the probability density function of the GSMaP_Gauge estimation multiplied by the Gauge term.
- The solution can be determined by calculating the dL/da = 0 equation

Distribution of precipitation

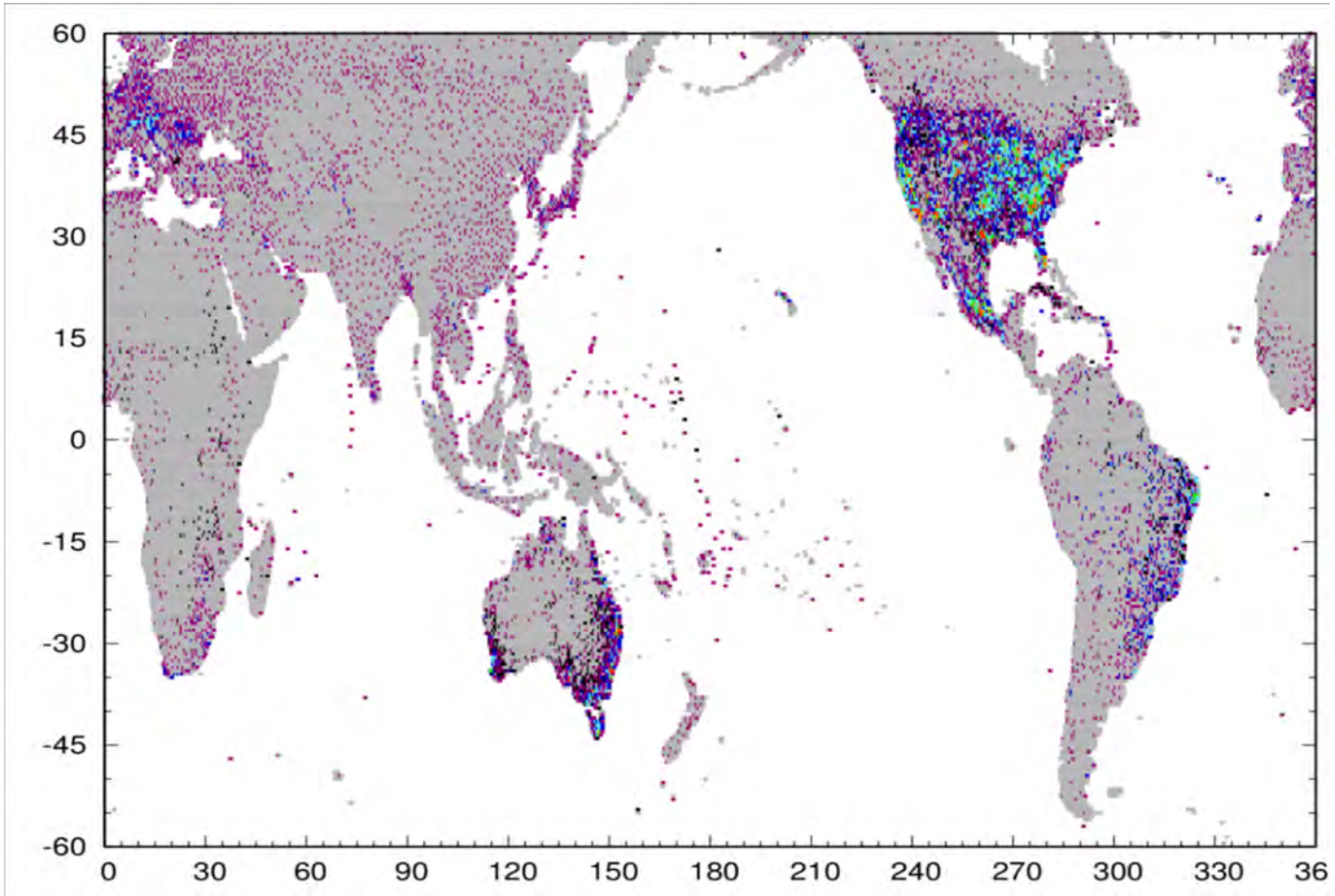
August, 2010



- GSMaP MVK
  - Precipitation patterns are different; such as India, Central Africa and Australia.
  - Overestimation in Siberia and south America.
- GSMaP Gauge
  - Estimated precipitation pattern is more similar to CPC.
  - The algorithm succeeded in removing overestimation in Siberia and South America.

Mean rain gauge number used in GSMaP

2015 Jun.



Distribution of rain gauges is not uniform.

GSMaP Gauge model

$$\begin{cases} \boldsymbol{x}_{n+1} &= \boldsymbol{x}_n + \mathcal{N}(\mu_w, \sigma_w^2) \\ \boldsymbol{y}_n &= c\boldsymbol{x}_n + \mathcal{N}(\mu_v, \sigma_v^2) \end{cases}$$

Weighting function

$$J(\boldsymbol{x}) = J_1(\boldsymbol{x}) + \lambda J_2(\boldsymbol{x}, W)$$

$$J_1(\boldsymbol{x}) = -\ln \Pr(\boldsymbol{x}, \boldsymbol{y})$$

$$J_2(x) = \frac{1}{2}\left(\sum_{n=1}^{24} \boldsymbol{x}_n - W\right)^2$$

$\boldsymbol{y}_n$	: Estimated precipitation rate (GSMaP MVK)
$\boldsymbol{x}_n$	: Precipitation rate
c	: Coefficient of proportionality of the estimation of precipitation
$\mathcal{N}$	: Standard distribution
μ_v	: Variance of estimation error
μ_w	: Change rate of precipitation
σ_v	: Estimation error
σ_w	: Variance of precipitation
W	: Daily precipitation
n	: hour
$\Pr(\boldsymbol{x}, \boldsymbol{y})$	: Probability of $\boldsymbol{x}$ and $\boldsymbol{y}$ (Gaussian distribution)
λ	: weight

W: NOAA CPC Unified Gauge-Based Analysis of Global Daily Precipitation(CPC)

Two equations

1. Temporal changes of precipitation rate is normal distribution.
2. Observation and real precipitation have a liner relation plus noise factor.

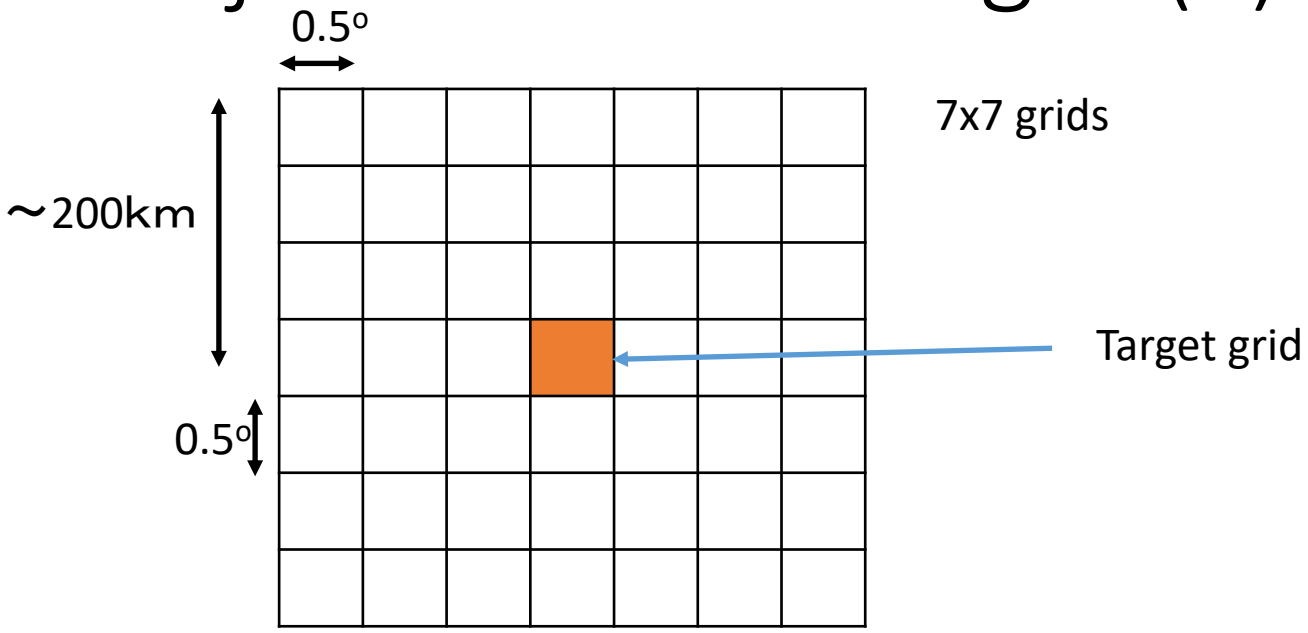
Minimize $J(\boldsymbol{x})$ function

GSMaP Gauge algorithm of V7 change weight（λ） by number of rain gauge of CPC.

Weighting parameter λ

- In V6, constant value was used in the algorithm.
- In V7, this weighting value has been changed according to the number of gauges per pixel.

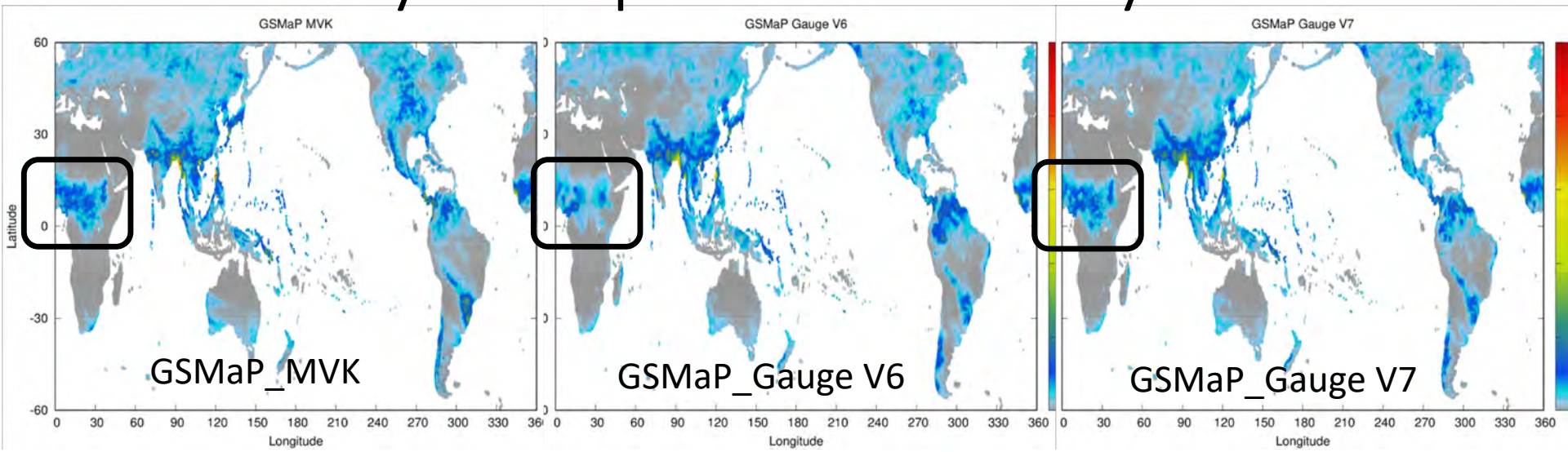
Adjustment of Weight (λ)



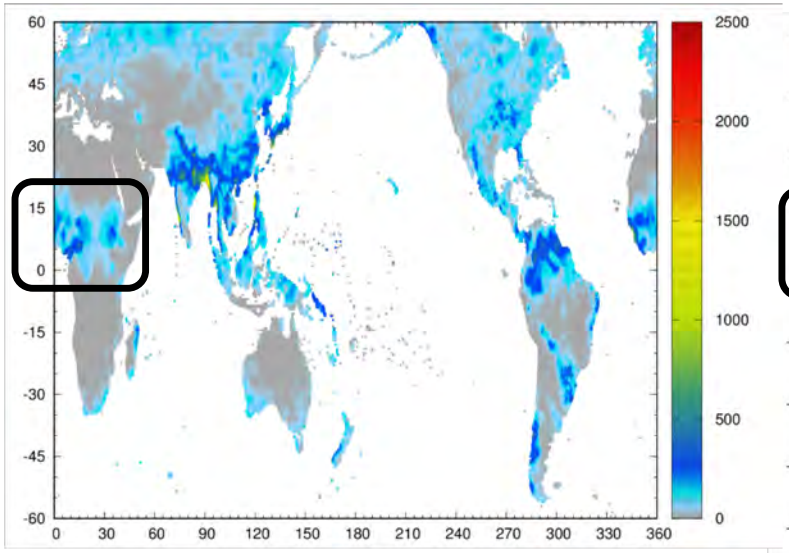
- Weight (0-0.5) was changed by the number of rain gauges.
  - $\lambda = \lambda_0$ for n>=5
  - $\lambda = n/5 * \lambda_0$ for n<5

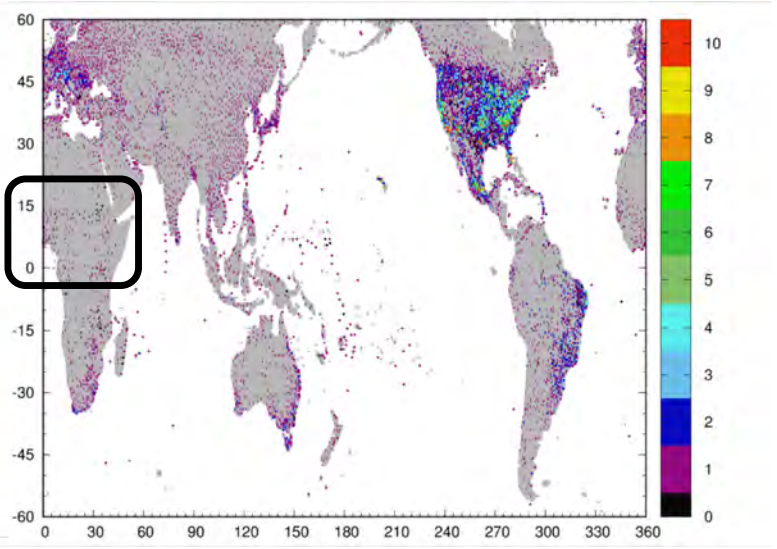
    λ_0=0.5, n=number of rain gauge in the 7x7 grids.

Monthly Comparison for July 2015

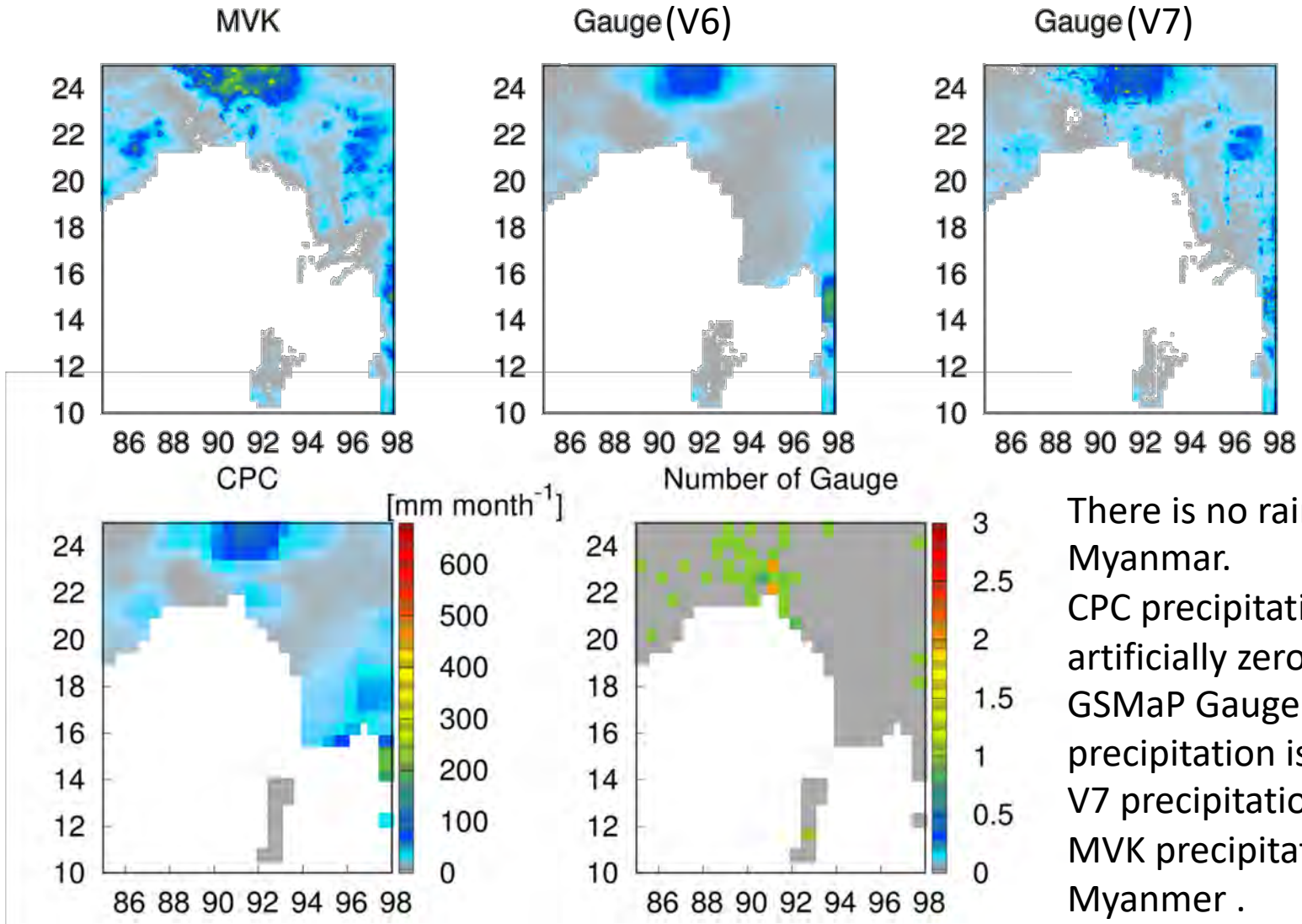


CPC





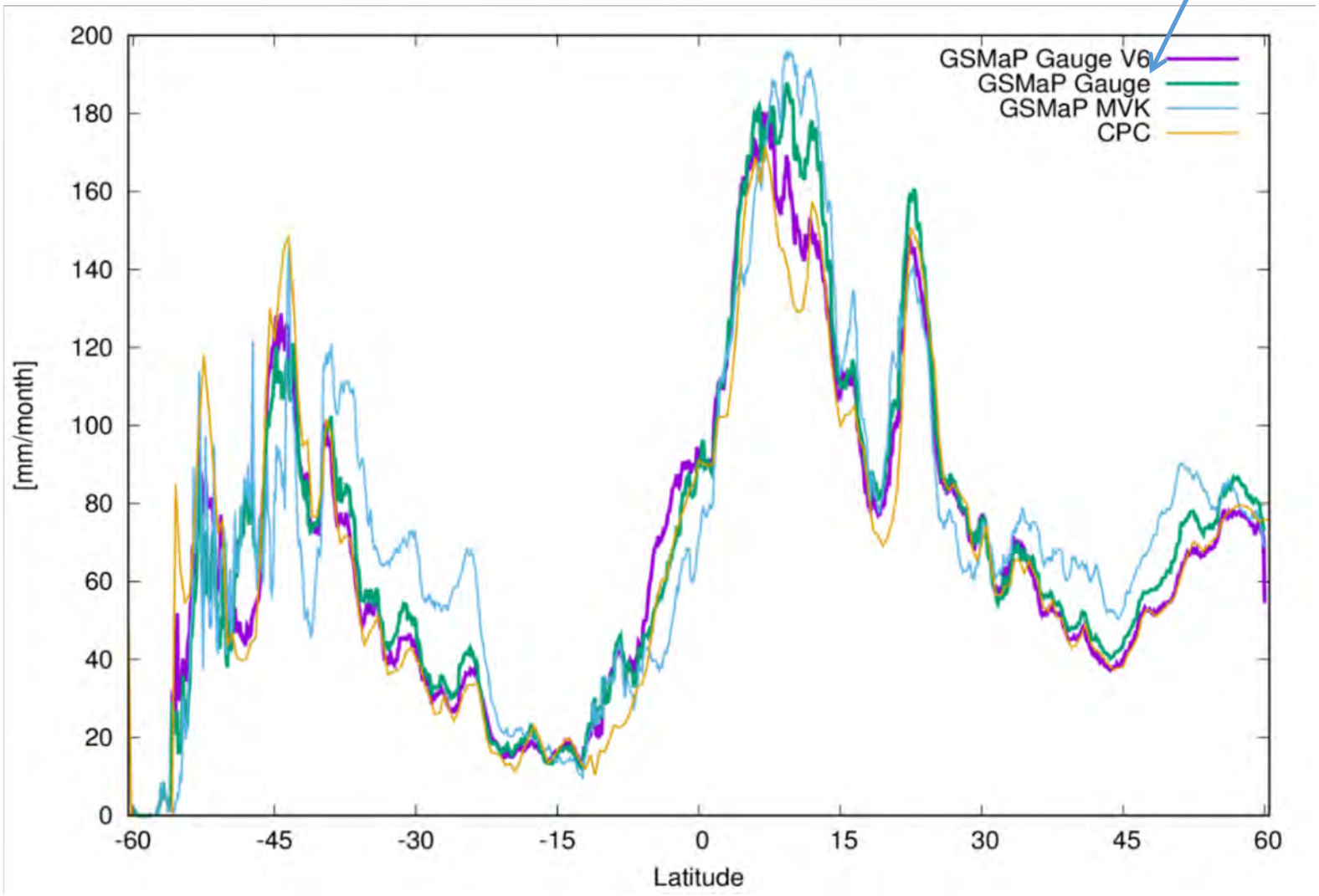
Monthly precipitation rate (April 2014)



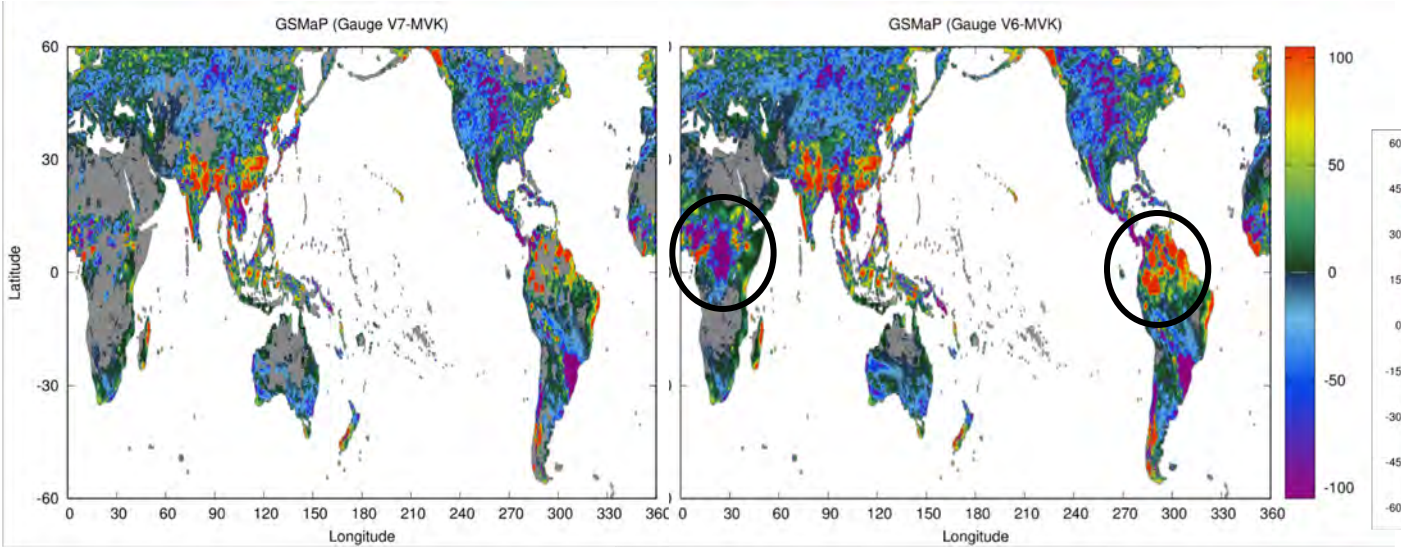
There is no rain gauge in Myanmar.
CPC precipitation is artificially zero in Myanmar.
GSMaP Gauge V6 precipitation is too weak.
V7 precipitation similar to MVK precipitation in Myanmer .

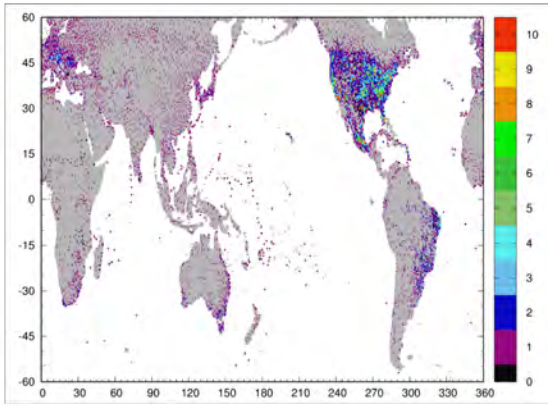
GSMaP_Gauge V7

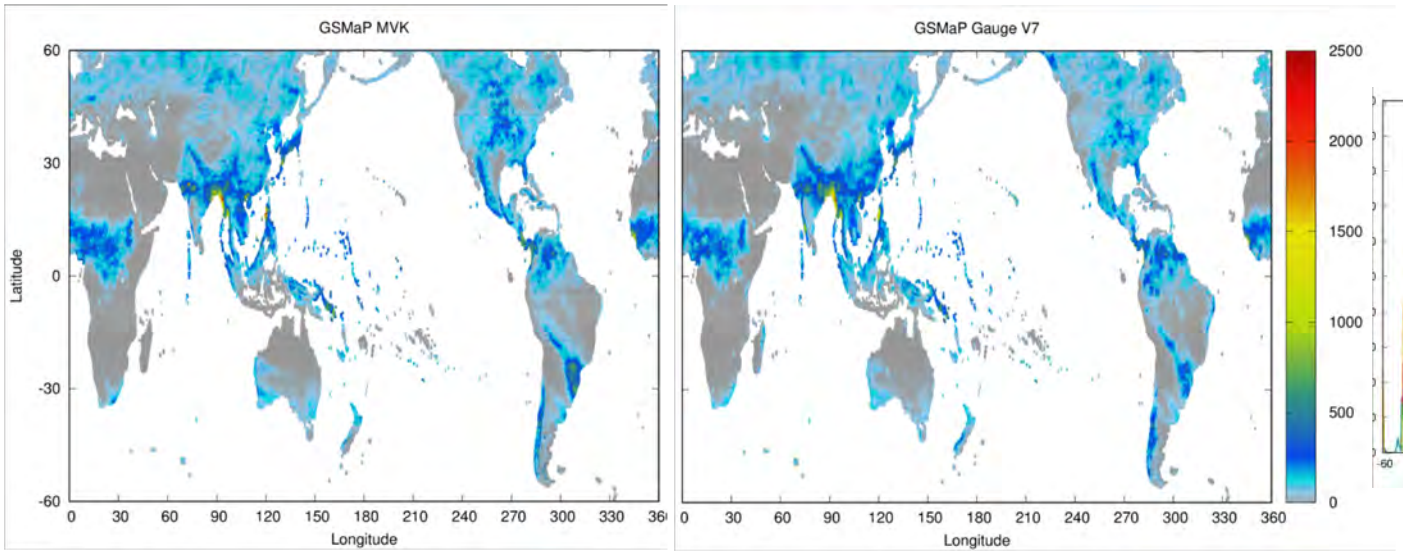
Zonal mean (July, 2015)

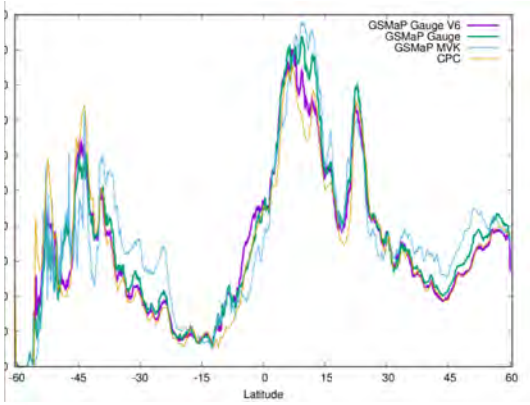


Difference July, 2015



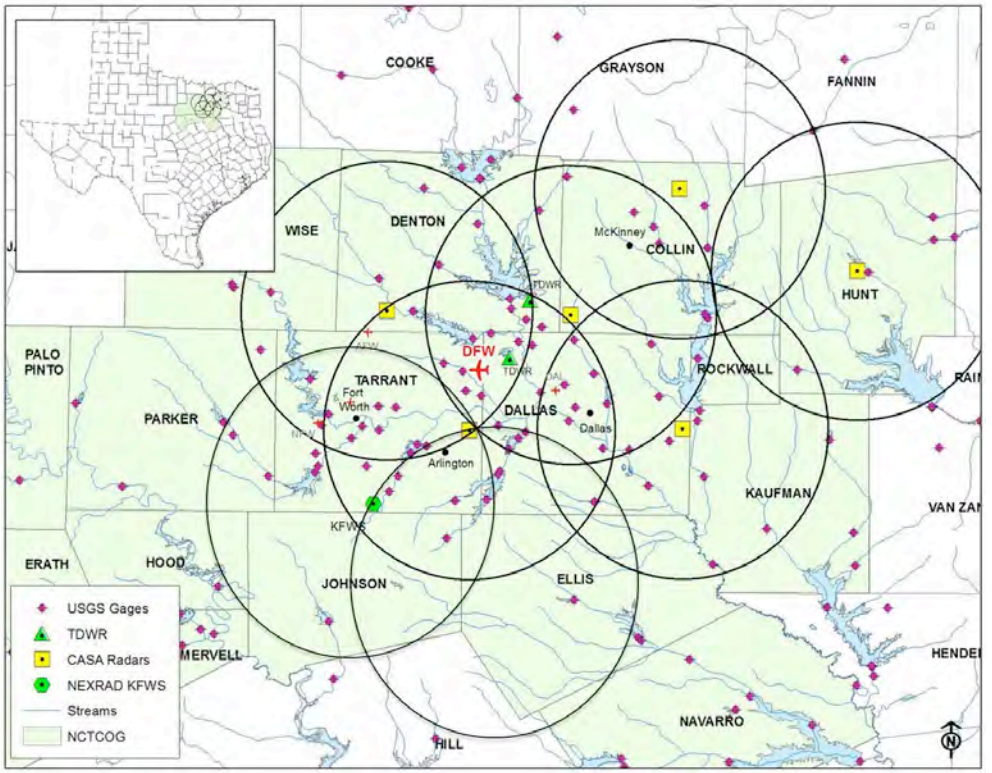






CASA Radar Network in DFW

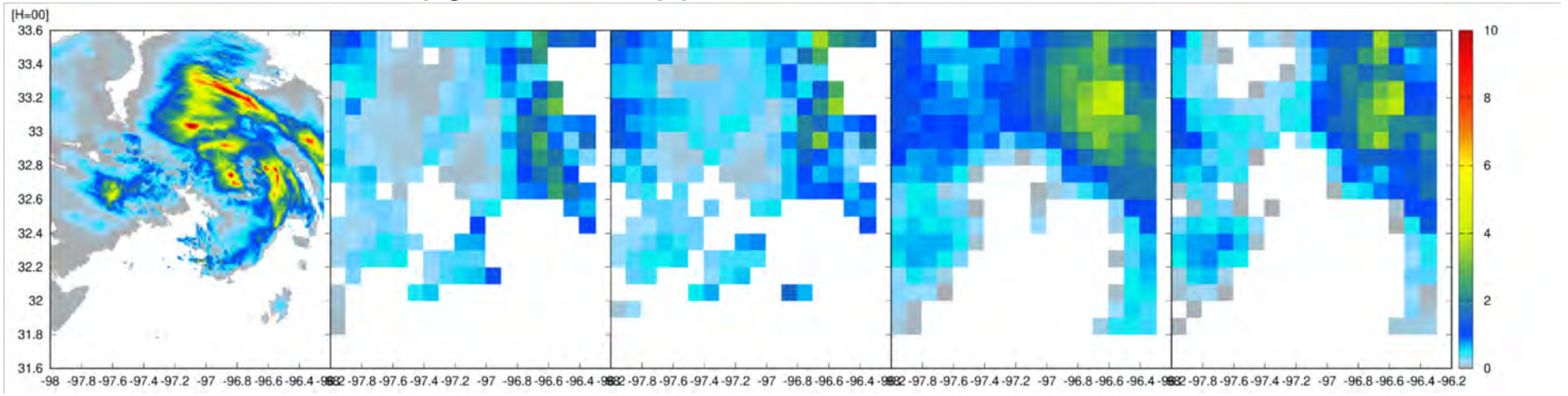
- In total, eight dual-polarization X-band radars are deployed in this urban remote sensing network to demonstrate improved hazardous weather forecasts and warnings in a densely populated environment. Here is a layout of the eight radars.
- More accurate areal rain rate can be obtained by dual polarization radar network than by rain gauges.
- Period:
  - May 26-27, May 29 –June 3, July 4-5, November 2-3, November 5-8



DFW, GSMaP_MVK, and GSMaP_Gauge

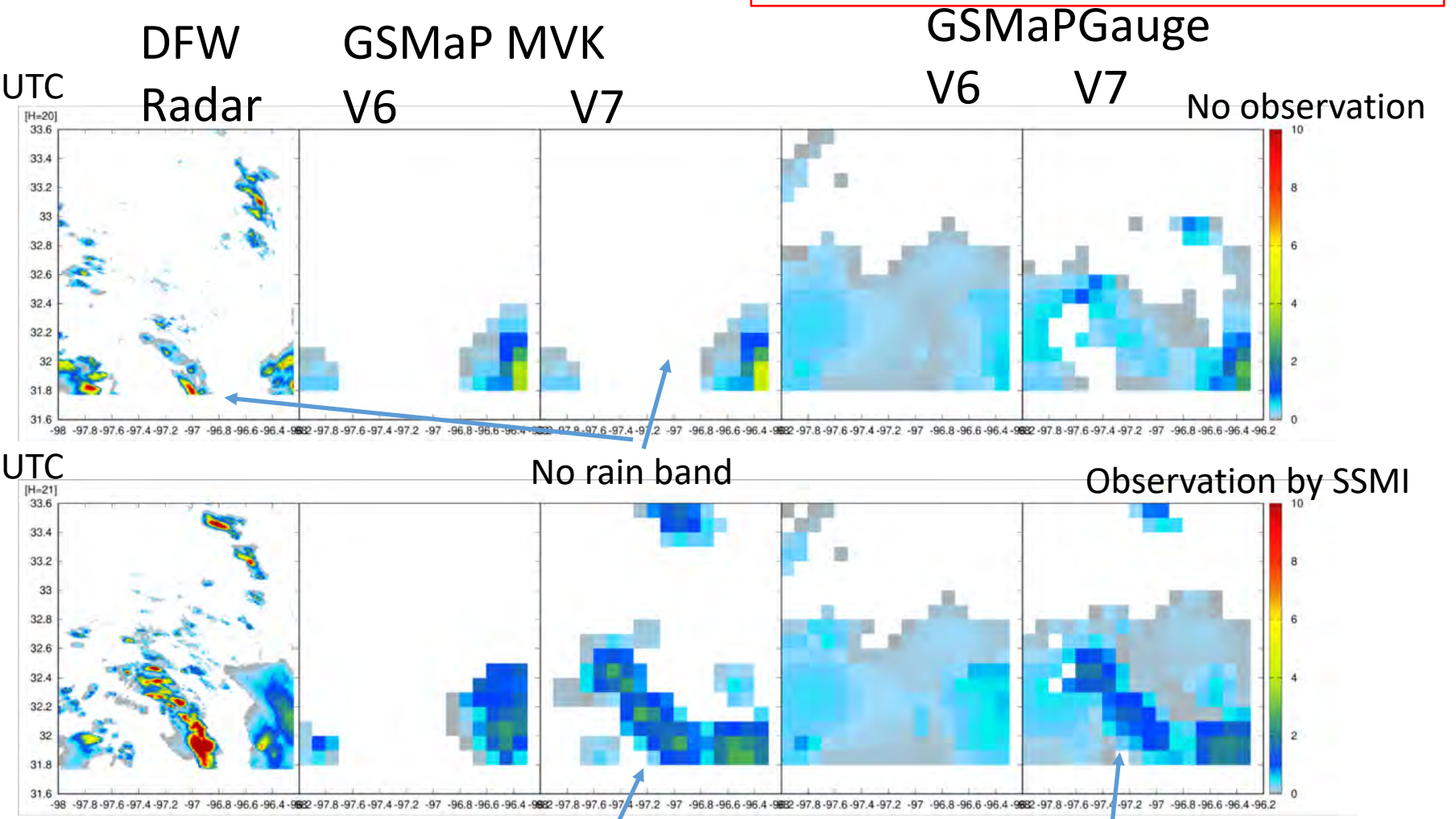
00UTC

DFW Radar | GSMaP_MVK V6 | GSMaP_MVK V7 | GSMaP_Gauge V6 | GSMaP_Gauge V7

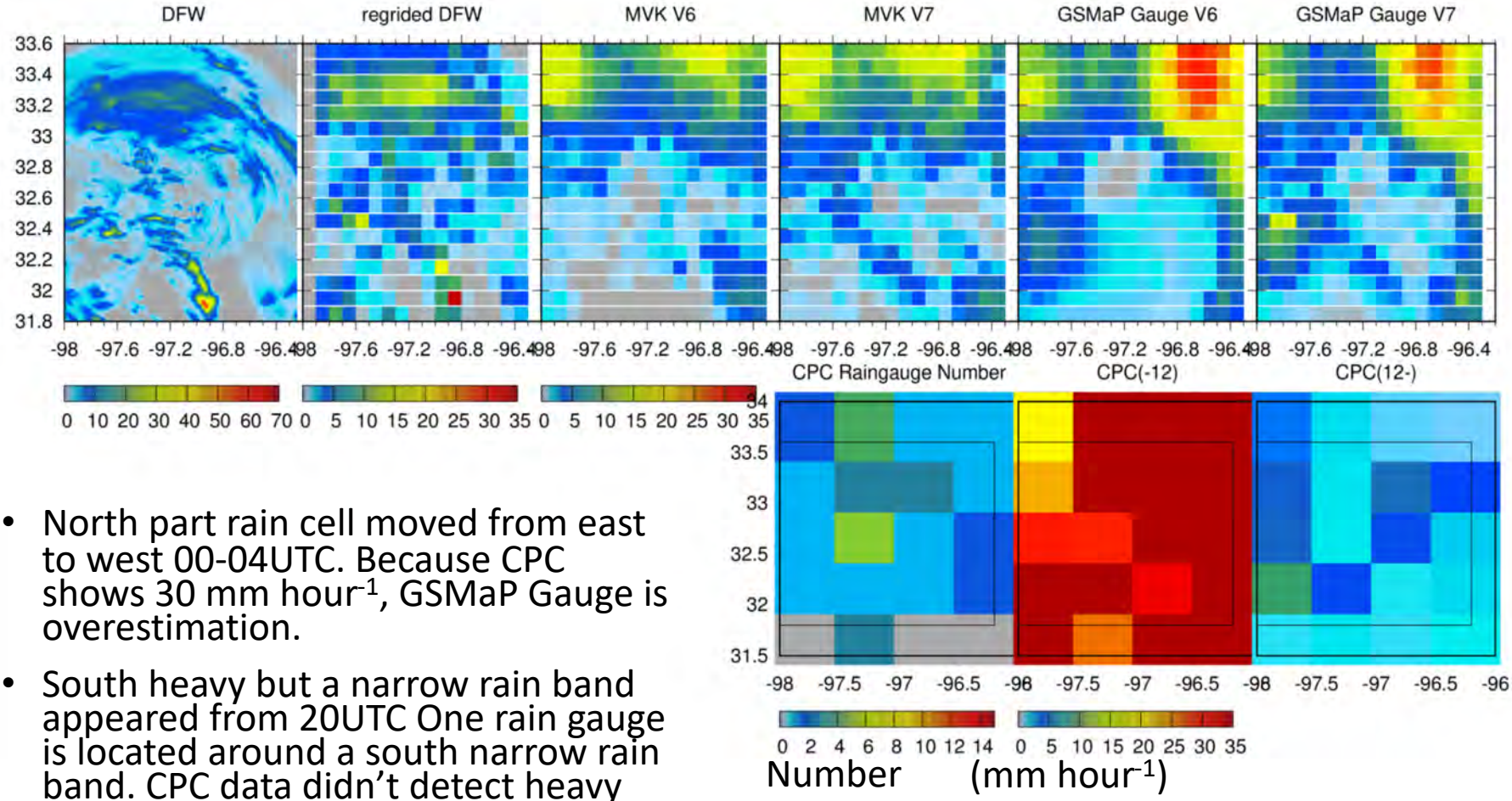


Narrow rain band

Some improvements are seen in hourly scale comparison in the new version.



24 hour precipitation



- North part rain cell moved from east to west 00-04UTC. Because CPC shows 30 mm hour^{-1}, GSMaP Gauge is overestimation.
- South heavy but a narrow rain band appeared from 20UTC One rain gauge is located around a south narrow rain band. CPC data didn't detect heavy rain. So GSMaP Gauge under estimated the rain band.

On the Rain Detection

GSMaP MVK		DFW Radar	
		Rain	No rain
Rain	V6	11628	16155
	V7	11846	15722
No rain	V6	2962	86759
	V7	2744	87192

GSMaP GAUGE		DFW Radar	
		Rain	No rain
Rain	V6	12201	18124
	V7	12091	15870
No rain	V6	2389	84790
	V7	2499	87044

- Red indicate better than other version.

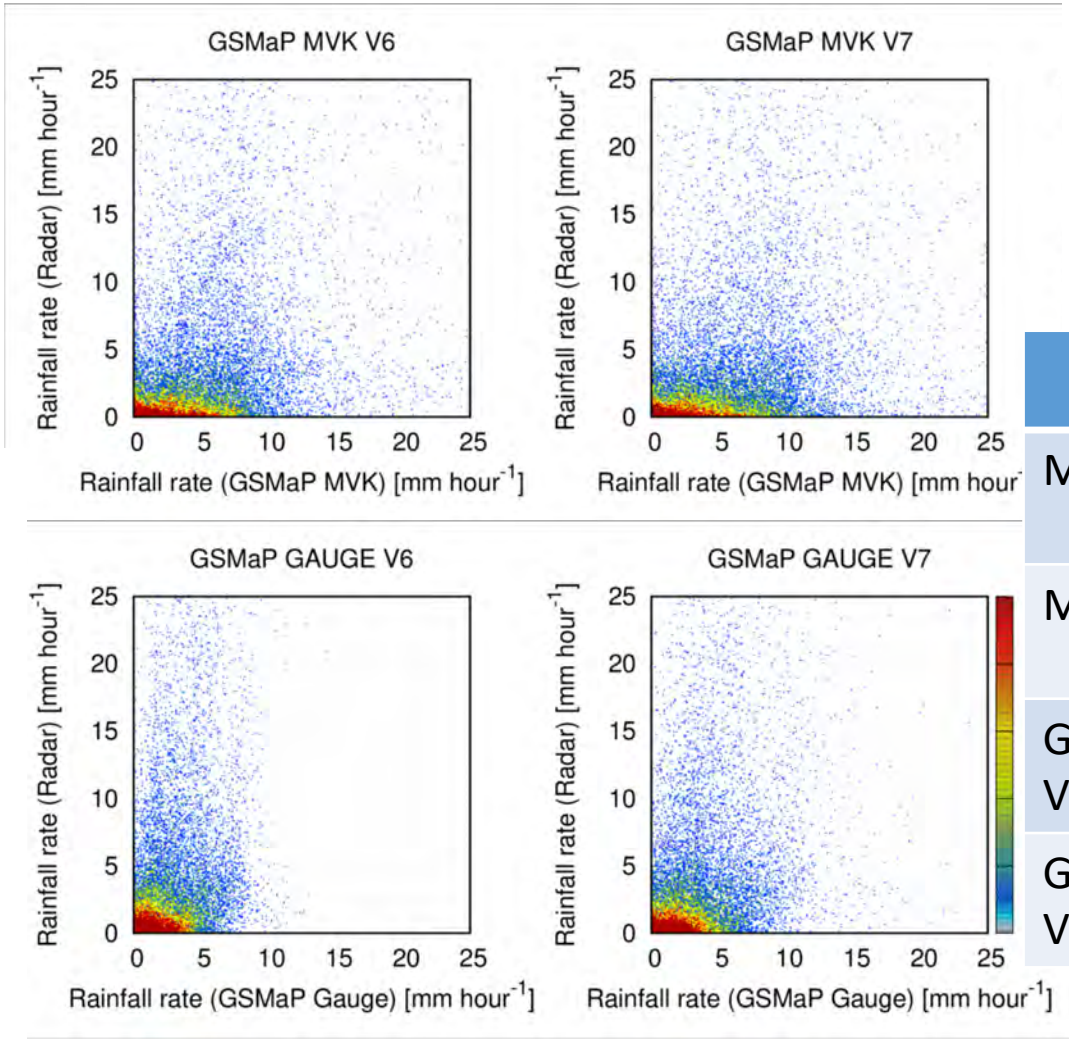
Validation

	POD	FAR	TS	ETS
MVK V6	0.797	0.582	0.378	0.300
MVK V7	0.812	0.570	0.391	0.313
GAUGE V6	0.836	0.598	0.373	0.291
GAUGE V7	0.829	0.568	0.397	0.319

- GSMaP MVK V7 is better than MVK V6.
- Although GSMaP Gauge V7 slightly reduce POD (0.007), FAR is reduced by 0.03. GSMaP Gauge V7 improve TS and ETS.

POD Possibility of detection
FAR False alarm ratio
TS Threat Score
ETS Equitable Threat Score

Scatter plot



	Regression line	Correlation
MVK V6	$R_{radar} = 0.501R_{MV6}$	0.480
MVK V7	$R_{radar} = 0.407R_{MV7}$	0.471
GAUGE V6	$R_{radar} = 0.840R_{GV6}$	0.494
GAUGE V7	$R_{radar} = 0.751R_{GV7}$	0.519

Some comments on the 1 hour res. GSMaP_Gauge

- Correlation still remains around 0.5, even if in a relatively dense gauge network.

- How much can we raise the performance particularly in hourly scale?

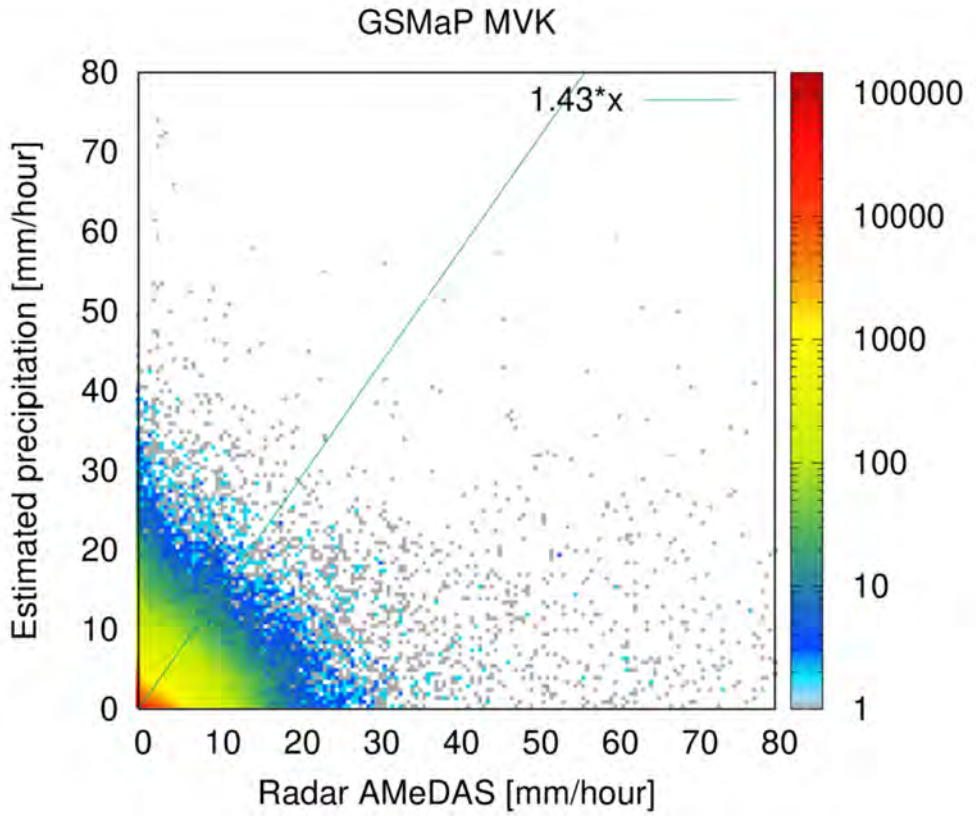
- One way to improve the GSMaP_Gauge estimation, is to implement dynamic table in the GSMaP_Gauge algorithm.

System Model of the GSMaP_Gauge product

$$\begin{cases} GSMaP\_Gauge_{t+1} = GSMaP\_Gauge_t + \sigma_{w_t} \\ GSMaP\_MVK_t = c \times GSMaP\_Gauge_t + \sigma_{v_t} \\ \sum_{t=1}^{24} GSMaP\_Gauge_t = CPC\_Gauge \end{cases}$$

Parameters characterizing precipitation estimation

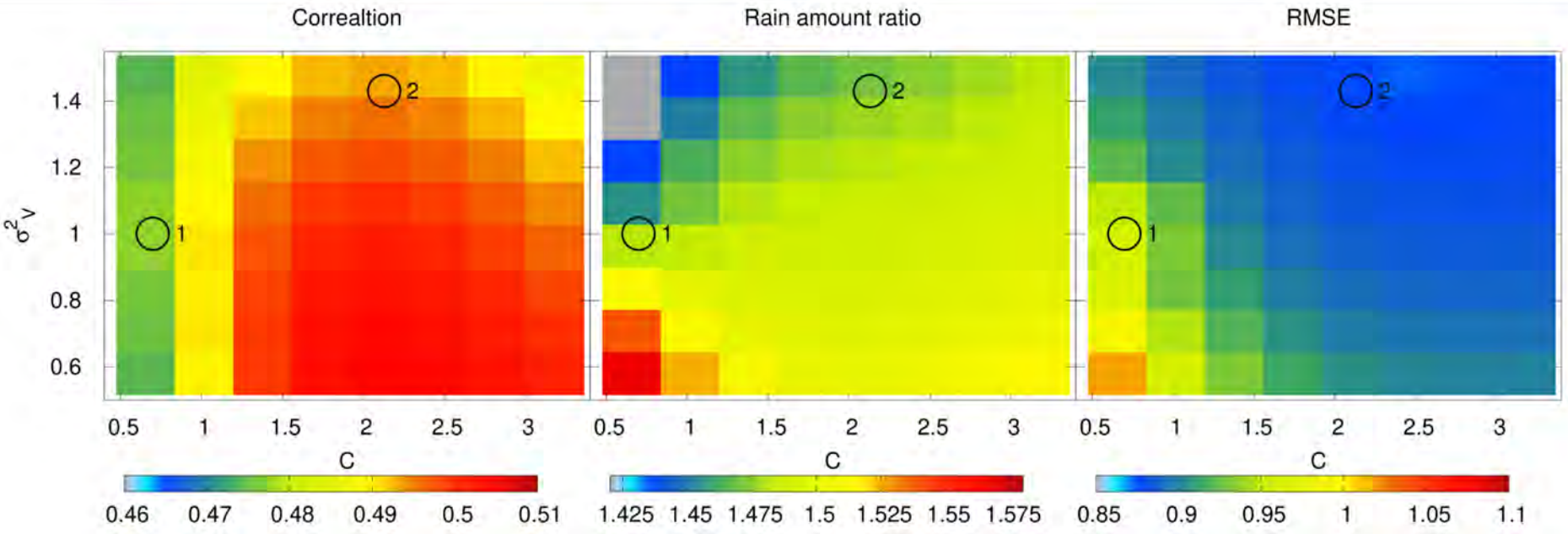
Estimation c & σ_v^2



1. We calculate a regression line between precipitation MVK and ground Radar.
2. C is a coefficient of regression line. Mean is Zero. Variance calculate from regression line.

	Current Value	September		August		Oct.
		V6	V7	V6	V7	V7
c	0.7	1.43	1.60	1.63	1.86	2.16
σ_v^2	0.5	2.13	2.49	2.36	3.27	1.59

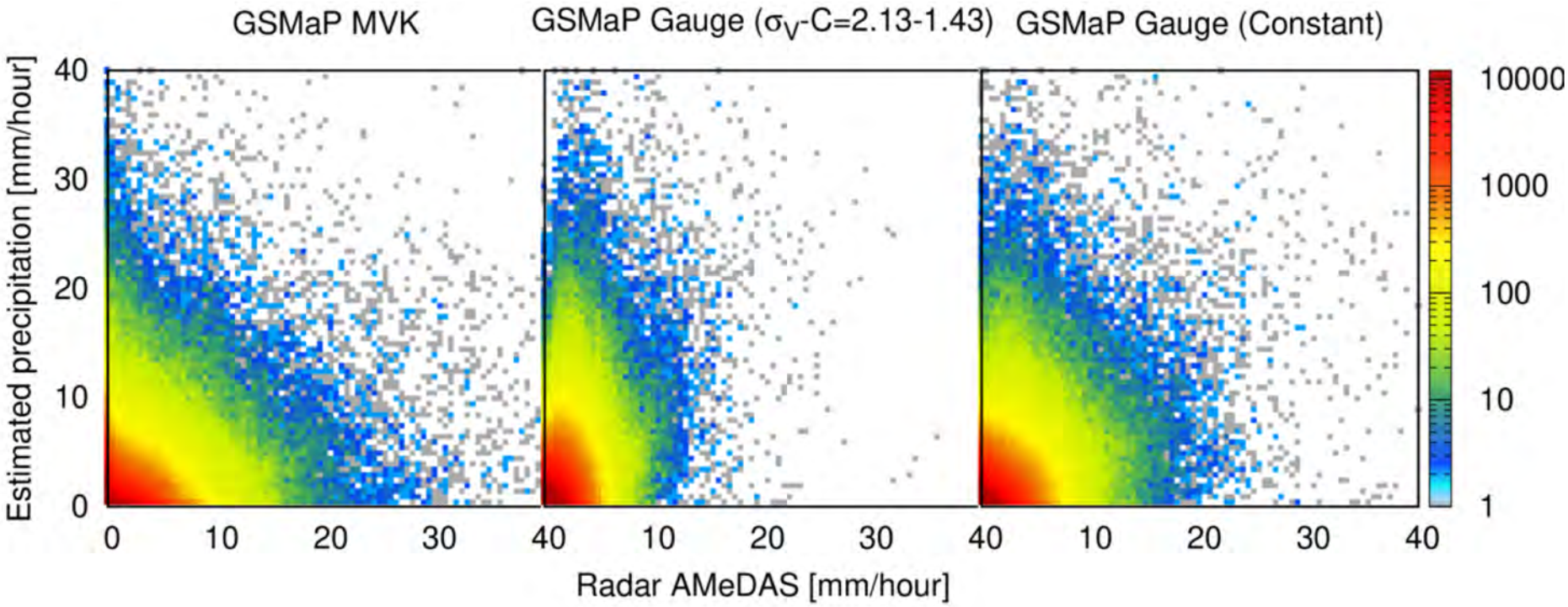
September (V6)



	Correlation	Ratio	RMSE
GSMaP MVK	0.381	1.43	1.24
GSMaP Gauge (Constant)[1]	0.457	1.59	1.06
GSMaP Gauge[2]	0.494	1.48	0.880

Ratio: Ratio of rain amount (One indicate Estimated rain amount equal to Radar rain amount.)

September(V6)



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GSMaP Gauge	0.494	1.48	0.880

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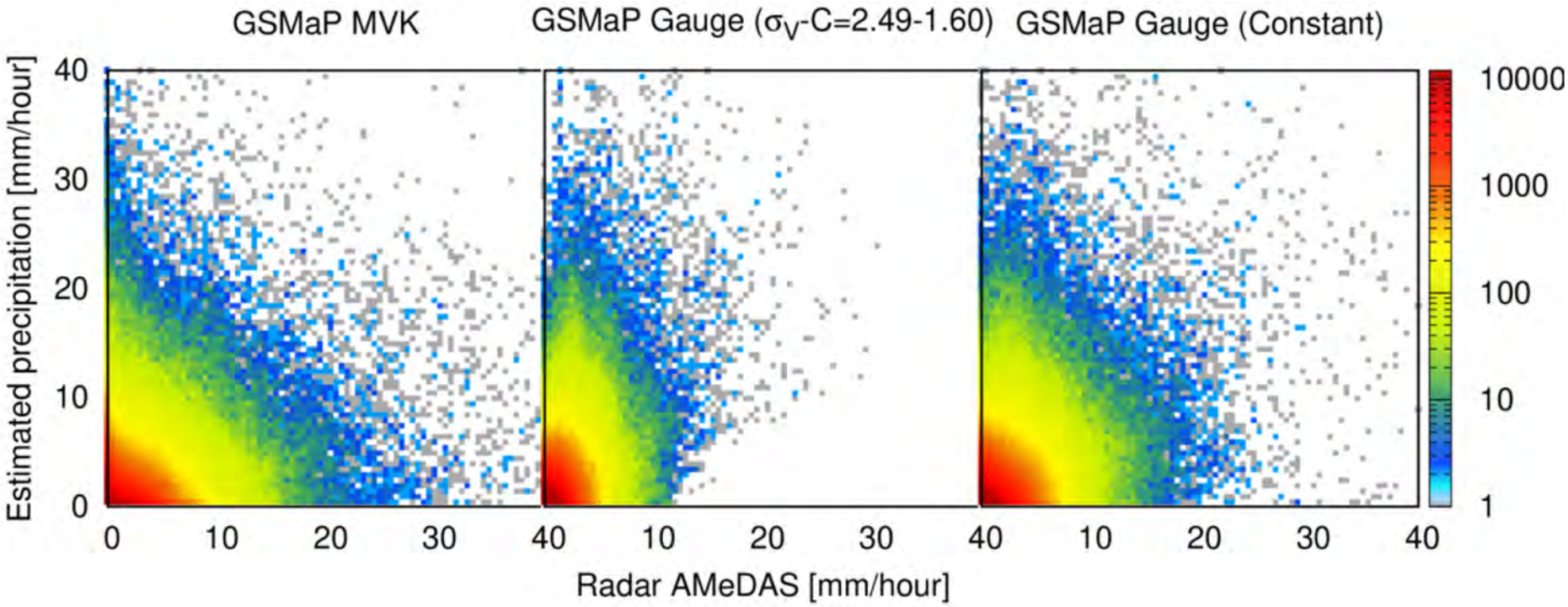
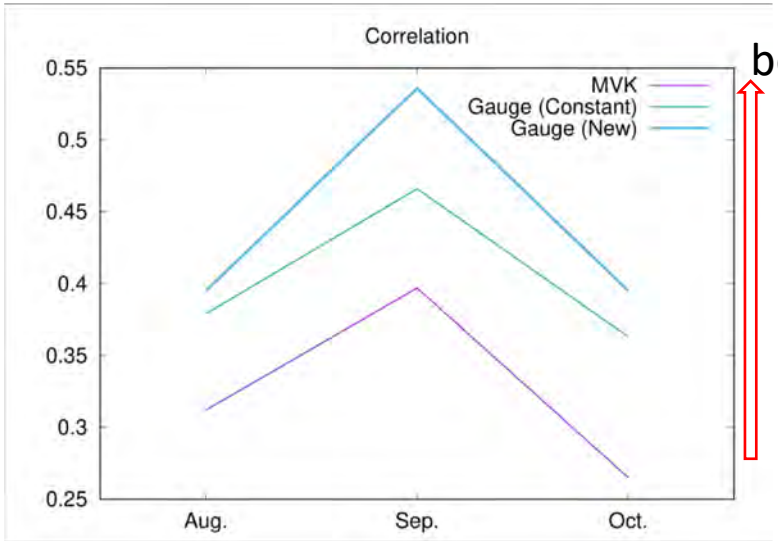
September(V7)



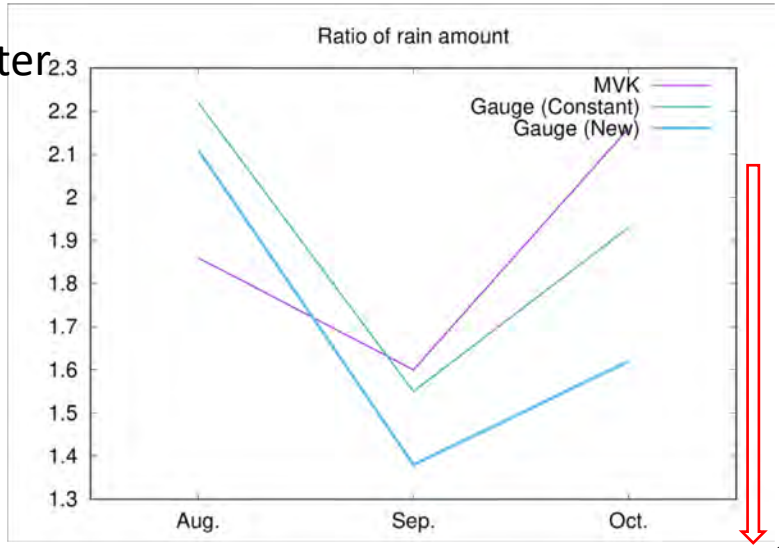
	Correlation	Ratio	RMSE
GSMaP MVK	0.397	1.60	1.34
GSMaP Gauge (Constant)	0.466	1.55	1.05
GSMaP Gauge	0.536	1.37	0.795

Ratio: Ratio of rain amount (One indicate Estimated rain amount equal to Radar rain amount.)

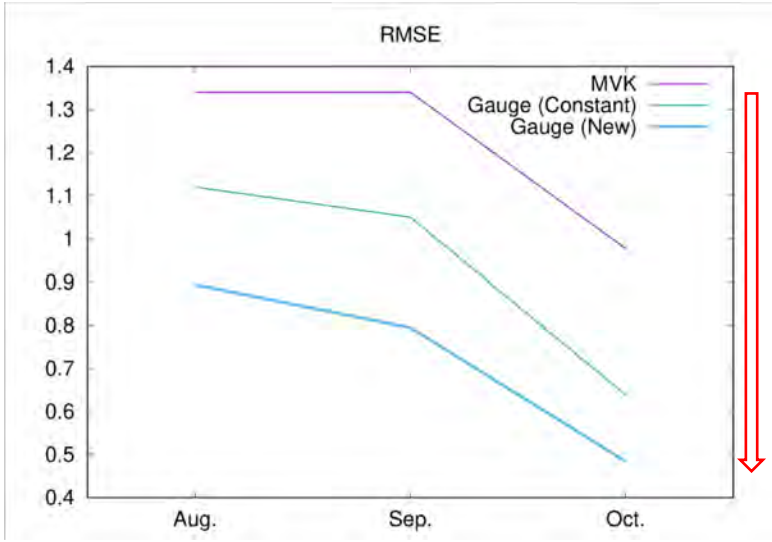
Validation of Monthly rain



better



1.0 is best



better

In monthly scale, the performance of the GSMaP_Gauge with optimal parameters is totally better than with the current constant parameters.

Summary

- Some optimization scheme was introduced in the new version of the GSMaP_Gauge algorithm.
- Weighting optimization
  - Performance of GSMaP V7 is better than GSMaP V6.
  - Even if in a dense gauge network area, the correlation of the GSMaP_Gauge still remain around 0.5 in hourly scale.
- Parameter of GSMaP Gauge
  - Model parameters are calculated from MVK and Radar AMeDAS.
  - The optimized parameters lead GSMaP_Gauge to better performances.
  - Probably it is better to implement the dynamic table of the model parameters.